MEGA—Micro-fabricated Electron Gun for Atomic Clocks

D. Faralli, M. Dadras, S. Ischer, F. Droz, M. Despont, D. Bayat, S. Unterhofer

A cold electron emitter is fabricated as an alternative to standard hot-filament emitters. The device is a "Field Emitter Array" based on the known effect of the increase of electric fields in proximity of a sharp tip. A dense array of tips is fabricated using platinum silicide and integrated with a gate electrode done with the same material. The cold emitters will be used in the next generation of atomic clocks, where the use of hot filament emitters has a number of drawbacks. The samples will be assembled in a dedicated flange for testing of the emissivity in a UHV system, down to 10^{-10} mbar.

Atomic clocks by "trapped Hg ions" are being developed for next generation of space and ground applications, due to their potential for superior stability over long period of time. An essential element of these clocks (Figure 1) is the electron gun, which is operated periodically to ionize the Hg atoms present in the resonant chamber. The standard "hot filament" electron guns have a number of drawbacks such as high-power consumption, very slow on/off switching response, form factor, weight and noise (thermal and magnetic).

Figure 1: Draft of an "Hg trapped ion" atomic clock [1].

It is known that electron emission can be achieved at room temperature (cold emitters) by using the "tip effect", *i.e.*, the enhancement of electric field at a sharp tip. An array of tips can be micro-fabricated and integrated with a gate electrode to achieve electron emitted current in the order of 1-100 µA.

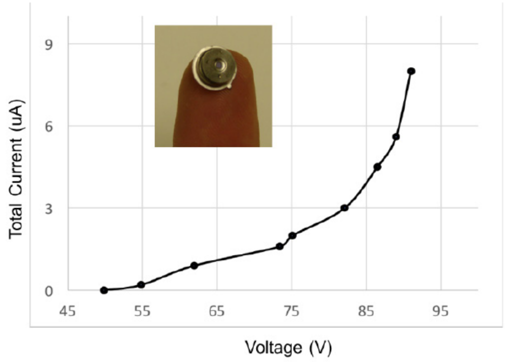

Figure 2: Picture and V/I characteristic of a Field Emitter Array [2].

In Figure 3 the cross section of a Field Emitter is shown. The cathode/tip is fabricated on the substrate and is separated from the gate electrode by an insulator. At a threshold voltage of 20-40 V the emission starts, and the electrons generated are collected by the anode, which is placed in the ion trap.

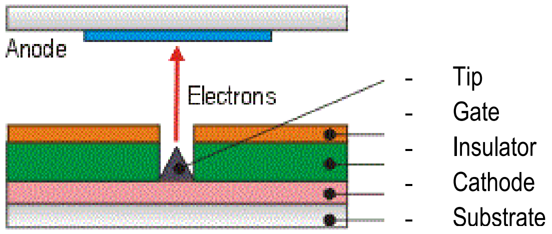

Figure 3: Schematic cross-section of a typical field emitter.

The emitted current is given by a Fowler-Nordheim relation:

$$I = J \times \alpha = A \times V_g^2 \exp(-B/V_g)$$

where Vg is the voltage between Gate and Cathode and A, B parameters that depend mostly by the tip material work function and sharpness as well as the gate geometry.

In this project we use platinum silicide as material for the tips and for the gate electrode, due to its low work function, low resistivity and excellent resistance to electromigration.

The tips are initially formed on the silicon substrate using an isotropic dry-etch process followed by thermal oxidation for sharpening. A platinum layer is sputtered and annealed @700°C for silicide formation. A self-align process is used to pattern both tips and gate electrode.

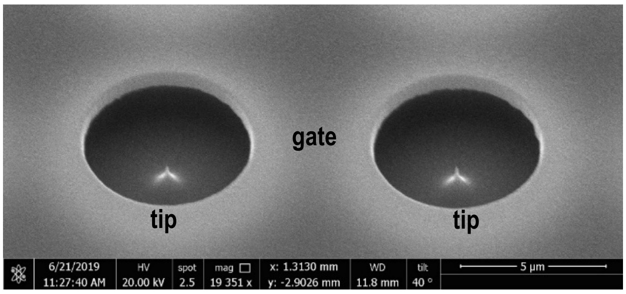

Figure 4: SEM picture of two tips from MEGA technology.

In Figure 4 an example of the micro-fabricated tips and gate electrode is shown. Arrays at different size and density have been designed, ranging from 1.000 to 40.000 tips.

The device will be assembled in a dedicated vacuum flange and mounted in a UHV vacuum system to characterize the current emission as a function of the Vg voltage at different vacuum level, down to 10^{-10} mbar.

The project is supported by the MdP18 program, coordinated by the Swiss Space Center and funded by the Swiss Space Office of SERI (State Secretariat for Education, Research and Innovation).

[1] G. K. Gulati, *et al.*, "Miniatured and low power mercury microwave ion clock", abstract IFCS 2018, May 21-24, 2018.

[2] G. K. Gulati, *et al.*, "Miniatured and low power mercury microwave ion clock", abstract IFCS 2018, May 21-24, 2018.